RESEARCH POSTER PRESENTATION ABSTRACTS

(in alphabetical order by author)

Geometry and Composition of Ice Banks in a Macrotidal Channel

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Large ice blocks containing enough sediment to be denser than sea water form in the Minas Basin of the Bay of Fundy. Timing of block formation and block composition were monitored to improve understanding of the potential threat to tidal power generators posed by collision with blocks. Large blocks are produced from ice cliffs that form when anchored ice obstructs tidal channels and decreases flow speed. Decreased flow causes channel cross-sectional area to decrease. In 2012 cross-sectional area of the Kennetcook River decreased by 28% due to formation of ice cliffs. Large ice blocks separated from the cliffs during the two spring tides following the maximum change in cumulative negative degree hours in the atmosphere. Ten percent of sampled ice blocks were denser than freshwater. Four of twelve ice cores collected from the ice cliffs along the Kennetcook contained enough sediment to become denser than seawater.

Seasonal Control of Biofilms on Sediment Erosion from an Intertidal Mud Flat in Kingsport, NS.

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Understanding sediment transport and supply in the Bay of Fundy is crucial to assess the effect tidal turbines will have on coastlines, as well as the threats suspended sediment may present. Ongoing research in the Minas Basin has identified seasonal cycles in the total suspended sediment mass. Models can reproduce the seasonal signal by altering the erosion rate of sediment in summer versus winter, but this hypothesized mechanism has not been tested. This research focuses on the seasonal effects of biofilms on sediment erosion from an intertidal mud flat in Kingsport, NS. Biofilms are thin microalgal mats found at the sediment surface, and they have been shown in other research to influence erosion rates. From April through November 2012, sediment cores were collected biweekly, and a Gust microcosm was used to simulate natural erosion at the sediment surface of the cores. For every collection day, half of the eroded cores remained untreated to assess the natural erosion behaviour of the mud flat. The other half of the eroded cores was treated with bleach to destroy the natural biofilm. By comparing properties of the sediment eroded from each set of cores, the effects of biofilms on erosion were inferred. Results show that, without biofilm, mud flats display a similar erosion behavior throughout the sampled seasons, and that differences between collection dates can be explained by biofilms and other biological factors.

Modeling the Impact of Large-Scale Tidal Power on Sediment Texture in the Bay of Fundy

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The output of a 3-D ocean circulation model and information on nearly 10,000 sediment samples are used to examine the extent to which a model of ocean currents can be used to predict seabed sediment texture in the Bay of Fundy and Gulf of Maine. It is found that sediment texture is generally closer to equilibrium with maximum tidal bed shear stress in the Gulf of Maine than in the Bay of Fundy. In the Bay of Fundy, competent mean grain sizes are generally coarser than observed mean grain sizes, and further interpretation suggests that sediment supply has a dominant influence on texture. Furthermore, the impact on texture is predicted for two tidal power development scenarios in the Minas Passage (Hasegawa et al., 2011). For a 2.0 GW power scenario, a sediment fining is predicted in parts of Minas Passage, although the impact should be small as supply dominates texture. Further research is needed to quantify with more precision the potential impact of tidal power development on texture, especially in the Bay of Fundy.

Riding the Tide is No Bore: Temporal and Spatial Movement Patterns of Striped Bass in the Minas Passage, Bay of Fundy

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The Bay of Fundy's Minas Passage (5 km wide) is currently the site for in-stream tidal energy turbine testing, but is also a passageway for important migratory fish species. Among these is an endangered striped bass (*Morone saxatilis*) population. The objectives of this project were to determine the movement patterns of sub-adult and adult striped bass within the passage, and to assess the potential risk of interaction with tidal energy turbines. Transmitter-tagged striped bass (20 adults and 20 sub-adults) were tracked using 29 bottom-moored VEMCO acoustic receivers. Receivers traversed both sides of the passage and the turbine test area. All recovered receivers (n=27) logged valid detections, with the highest number of detections occurring in July. Of the 40 striped bass tagged, 25 were detected, with more adults detected (75%) than sub-adults (50%). Adult fish were detected throughout the water column, while sub-adults were detected only in the top 25 m (above turbine height). Fifteen striped bass (mostly adults) moved back and forth through the passage with swimming speeds between 1.20 and 3.56 m/s. Fish were detected more often at night than during the day. Detection frequency was higher during neap tidal cycles than during spring tidal cycles and was negatively correlated with current speed. Individual striped bass were shown to make multiple crossings of the Minas Passage during summer and many passed through the turbine test site at turbine hub height. The ability of striped bass to detect and avoid tidal turbines when travelling at high speed remains unknown.

Electrical Design Considerations of Submarine Power Cables

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We highlight results of a study of subsea cable properties influencing the transfer of power from marine renewable energy devices to shore. We treated many commercially available single and three core submarine power cables for ac applications. Electric circuit parameters were evaluated based on geometric configurations and material characteristics. Two-port network models were developed which allows determination of transient and steady state performance characteristics of the cables. Site-specific decisions as to whether to use ac or dc based on length to shore, power and voltage level at the point of common connection.

The study has shown that submarine cables have unique electrical characteristics that need to be taken into account when specifying transmission of power from the marine energy converters.

- Reactive power refers to actual power that shuttles back and forth to change motor windings Submarine cables provide considerable reactive power to the system.
- In the case where sending end power factor is lagging there is a line length where the receiving end power factor could be close to unity.

The receiving end voltage magnitude fluctuates (rises, maximizes, and then decreases) in submarine cables; for overhead lines the voltage tends to continually rise. One of the advantages is that a submarine cable could feed the reactive power demand of the electric power generators (induction and permanent magnet generators) that are commonly used in marine energy converters.

Acoustic Detection Ranges for Marine Mammal Monitoring at a Tidal Turbine Site: Grand Passage, NS.

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Passive Acoustic Monitoring (PAM) for marine mammals at tidal energy developments requires an understanding of site-specific acoustic detection ranges. Since underwater sound is used as a tool for detecting marine mammal presence via their vocalizations, sounds mimicking those of marine mammals were projected to assess the feasibility of a PAM system at a proposed small-scale (<2 MW) tidal energy site in Grand Passage, NS. Consecutive sweeps were transmitted with an Ocean Sonics underwater projector (*ic*Talk) from a rigid inflatable boat as it drifted over a moored Ocean Sonics hydrophone (*ic*Listen) in July 2012. A Nortek Vector velocity sensor co-located with the hydrophone measured the flow to determine the hydrophone's effective detection range over the phase of the tide. The conditions under which the projected sounds were detectable will be presented. Furthermore, the naturally occurring ambient noise in high-flow environments imposes rather severe constraints on detection limits. Noise reduction techniques were field-tested in an attempt to extend acoustic detection ranges. Ambient noise levels were measured with a drifting hydrophone to establish baseline acoustic conditions prior to turbine installation, relevant to the tidal project's environmental assessment process. This work will contribute to the future monitoring of marine mammal presence in the vicinity.

Measurements and Simulations of the Flow in Digby Neck Passages

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The development of small-scale tidal power is progressing in the lower Bay of Fundy. Three passages -- Grand Passage, Petit Passage and Digby Gut -- are all approximately 1 km wide and 4 km long; however, the dynamics within each passage are highly dependent on the local bathymetry and coastline. In particular, two passages are open-ended, while one is essentially closed at one end. In an effort to study these dynamics and to estimate the tidal power potential, a resource assessment of each passage was completed in 2012 using arrays of acoustic Doppler current profilers (ADCPs) and a high-resolution, unstructured grid, numerical model.

Unlike many resource assessments which utilize a single ADCP at a site of interest, in this study, five ADCPs were deployed simultaneously in each passage for approximately one month. The ADCPs were positioned predominantly in an along-channel configuration; however, in Grand Passage, a cross-channel configuration was implemented in an effort to test the model's ability to capture the highly variable flow past an island.

In this poster, the characteristics of the flow as measured by the ADCPs and as predicted by the model will be compared. The results will focus on the speed, direction and power density of the flow, as well as, on estimates of the frictional stress exerted by the flow on the sea floor. For each passage, the observed dynamics on both the tidal and supra-tidal timescales will be discussed and the performance of a typical Tidal-Energy Converter will be estimated.

Seasonal Migration of the American Lobster, *Homarus americanus*, through the FORCE Tidal Turbine Test Site and Minas Passage, Bay Of Fundy

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The American lobster commercial fishery is Canada's most valuable seafood export, with a significant portion of the catch sourced from the Bay of Fundy. According to local fishers, lobster populations within LFA 35 in the upper Bay of Fundy undergo seasonal migration, with movements into the Minas Basin in spring and outwards in the late fall, via the Minas Passage. Anecdotal information indicates that temperature is the dominant migratory cue. The Fundy Ocean Research Centre for Energy (FORCE) tidal turbine test site (est. 2009) is located within the Minas Passage and studies to assess the potential impacts on marine biota have commenced. The primary objective of our study was to use Vemco acoustic tracking technology to determine use of the Minas Passage and FORCE test site as a migration corridor. In November 2011, 85 adult American lobsters from the Minas Basin were fitted with V13 acoustic transmitters and numbered disc tags, and released near the site of capture. Twenty-six bottom-mounted receivers spanned the width of the Minas Passage in two arrays, east and west of the FORCE site; another three receivers were moored in the FORCE lease area. From fall 2011 to summer 2012, a total of 98,330 tag transmissions from 31 lobsters were recorded. Of these lobsters, 74% were detected on receivers in the northern half of the Minas Passage, including eight lobsters detected on receivers within the FORCE test site. Mean rate of movement in fall was 0.32 km/day (±

0.34 km/day). During spring 2012, 10 tagged lobsters were detected in Minas Passage (7 re-detects, 3 new detections), presumably returning to the Minas Basin. Movement between multiple arrays was shown for one tagged lobster, which had a mean travel rate of 0.35 km/day (± 0.08 km/day). Additional lobsters tagged in late 2012 will contribute to the assessment of movements during the winter months and will test the hypothesis that lobsters swim in the Minas Passage during very high flow periods.

Bottom Substrate and Associated Epifauna at the FORCE Tidal Turbine Test Site, Minas Passage, Bay of Fundy

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The crown lease area of the Fundy Ocean Research Centre for Energy (FORCE), along the north shore of the Minas Passage, is characterized by a glacially influenced sedimentary basin, interspersed with volcanic bedrock subject to considerable scouring. This study examines the seafloor and benthic habitat of the FORCE lease area and describes features on which tidal energy infrastructure will be installed. The study presents baseline data that will be useful in addressing potential environmental effects of demonstrating tidal energy technologies (e.g. turbines, moorings, cables). The benthic community of three berth areas and their associated cable routes was examined via qualitative and quantitative analyses of videographic material collected in 2008-2009. ImageJ photo software was used to analyze 1197 frames for geophysical features (substrate type, size) and abundance (or percent cover) of macrobiota. Relationships between biota and substrate type were examined. Although biodiversity in this high flow environment was low, the percent cover of *Halichondria panicea*, the yellow breadcrumb sponge, was often high and positively correlated with degree of exposed bedrock. Other taxa present, but in low numbers, include two species of seastar, white sponge, and anemones. Macroalgae featured prominently in the shallow regions (<10m) of the cable routes. The biological and physical features of the seafloor were mapped to better inform FORCE and tidal energy project developers about the characteristics of their berths. This study provides mesoscale baseline data for use in the determination of environmental impacts on and of subsea cables and mooring structures.

High Resolution Numerical Modelling of Digby Neck Passages

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Fundy Tidal Inc. has been awarded Community Feed-in-Tariffs for Grand Passage, Petit Passage and Digby Gut, which all have high energy flows that are close to landfall. The goal of this research project was to produce a high-resolution numerical model of the passages that could be used for site selection and characterization.

We use FVCOM with an unstructured grid that has a resolution of roughly 15m in each passage. High-resolution bathymetry was gathered and combined with accurate coastline data to produce a very accurate grid. Both 2D and 3D simulations are run for time periods of a few days to 40 days. The model results were validated against data collected from multiple ADCP deployments that were part of

the SW Nova Scotia Tidal Energy Resource Assessment. The model does an excellent job of predicting tidal elevation and basic tidal flow. It also predicts intra-tidal fluctuations in the flow at the correct locations and times. However, the magnitude of the fluctuations is generally too large, which can drastically increase the maximum speed measured at a site. In Digby Gut, where the bathymetry was of lower quality, the simulated tidal currents did not compare as well to the gathered data.

The project has illustrated that high-resolution numerical modeling can be an affective tool for site characterization – for example the spatial characteristics of flow fluctuations can be connected to bathymetric features. However, ensuring that fluctuations are modeled correctly and quantifying the fluctuations for resource assessment and site characterization is outstanding research.

The Commotion in the Ocean – Detecting Harbour Porpoises (*Phocoena phocoena*) at the FORCE Turbine Test Site in the Minas Passage, Bay of Fundy

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Tidal power development sites introduce potential risks to marine mammals. Our project was focused on an assessment of harbour porpoise (*Phocoena phocoena*) activity at the Fundy Ocean Research Centre for Energy (FORCE) turbine test site in the Minas Passage. In this location, the maximum tidal range is 13 m; surface current speeds peak at about 6 m/s. The study also involved a comparison of the performance of two hydrophone types, the Chelonia Porpoise Detector (C-POD) and the icListenHF (Ocean Sonics Ltd). Diel, tidal and lunar patterns in porpoise activity were examined during the entire month of August 2012. The data contribute to an assessment of the potential risks of turbine-porpoise interaction at the FORCE site. Two C-PODs and one icListenHF were bottom moored and co-located in the FORCE test area. Detection positive minutes (DPMs, click train detection within each minute) were used to indicate porpoise presence. The icListenHF recorded approximately 10x more DPMs than the C-PODs, reflecting a listening volume for the icListenHF that is about 11x that of a C-POD. There were more DPMs at night than during the day, and more DPMs on neap tides than spring tides. Ambient noise levels, which were highest during a spring tide and higher during flood periods than during ebb periods, resulted in some lost detection time. At very high current speeds, the performance of both hydrophone types was affected by noise interference, presumably due to bedload transport and likely also due to noise generated by mooring chain. This study and a hydrophone drift study planned for spring 2013 will help inform the design of future marine mammal impact assessment studies at high flow development sites in the region.

Seasonal Sedimentation and Hydrodynamics in a Bay of Fundy Tidal Creek and Salt Marsh System

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With the goal of characterizing the far field effects of tidal energy extraction on Bay of Fundy intertidal zones sedimentation, hydrodynamics and sedimentation rates were measured in a macrotidal creek and salt marsh system. Sediment deposition, current velocities and suspended sediment concentrations were collected over different seasonal conditions from May 2012 to March 2013. The

data were collected in a transect from the creek to the marsh surface to characterize the physical processes impacting sediment deposition in this system. Three high resolution elevation surveys were conducted to characterize the change in topography of the channel. During rain events, sediment deposition in the creek increased, but the sediment deposition on the marsh was not affected. Sediment deposition on the marsh bank, edge and surface increased with higher sediment availability during November and January. Suspended sediment concentration, along with sediment deposition, showed a decreasing trend from the creek to the marsh surface. Concentrations in the creek clearly varied by season, being higher during winter conditions, but concentrations on the marsh remained more uniform throughout seasons. Velocities on the marsh were highest on the marsh edge and lowest on the marsh bank. On the marsh surface and edge, velocities showed tidal symmetry while on the bank flood dominance existed. This data will be used to feed a high resolution sediment transport model in a companion project, and also serves to strengthen relationships between sediment deposition in a tidal creek and salt marsh with the factors which are influencing it.

Introducing a Dynamic Penetrometer for Geotechnical Tidal Energy Converter Site Assessment and Monitoring

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Cone Penetrometer Testing (CPT) using engine-driven, quasi-static offshore devices is required to gather in-situ geotechnical information of the upper meters of the seafloor. Such instruments allow the determination of sediment strength and pore pressure, but are sensitive with regard to the presence of rocky surfaces or cobbles, are deployable under mild hydrodynamic conditions only and are expensive. Recently, the small-scale dynamic penetrometer *Nimrod* was tested for early-stage geotechnical probing in Grand Passage, Nova Scotia, a proposed tidal energy converter site in the Bay of Fundy. The probe was developed for rapid geotechnical characterization of surficial seafloor sediments and estimation of sediment dynamics in subaqueous areas of difficult access (strong hydrodynamics, close to offshore structures, etc.). The results from two surveys carried out with *Nimrod* in 2012, indicate that areas of different geotechnical characteristics corresponding to variations in grain size, geomorphology and bathymetry were mapped successfully, and the amount of poorly consolidated surficial sediment available for sediment transport was assessed. Areas of higher sediment mobility were identified and correlated to the existence of large-scale bedforms. The technique proved to be suitable for early-stage geotechnical surveying and the investigation of ongoing sediment dynamics relevant for the installation of tidal energy converters. It also potentially represents a cost- and time-efficient method to monitor changes in surficial sediment texture and sediment dynamics under different hydrodynamic conditions, and for the investigation of scour and potential weak layer development in the wake of tidal energy converters post-installation.

Observations of Harbour Porpoise (*Phocoena phocoena)* at the Fundy Tidal Energy Demonstration Site, Minas Passage, Nova Scotia, 2009-2012.

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Harbour Porpoise *(Phocoena phocoena)* are small cetaceans found on north temperate continental shelves of the north Pacific and Atlantic, and in Eastern North America from North Carolina to 70 º N, with sub populations in the Bay of Fundy-Gulf of Maine, Gulf of St. Lawrence and Newfoundland-Labrador. Populations in the Bay of Fundy-Gulf of Maine system are about 90,000 but the current population trend is unknown. The species is listed as threatened under the Canadian *Species at Risk Act*. Harbour Porpoise are commonly seen in the inner Bay of Fundy, but records of its local distribution and abundance are scarce. It was observed during baseline environmental monitoring surveys for marine mammals and seabirds conducted in Minas Basin, Minas Passage, and Minas Channel from 2009 to 2012 for the FORCE Fundy Tidal Energy Demonstration site, and was a relatively common visitor to the demonstration site during shore-based seabird surveys in 2010-2012. The species occurred from early March to late-November in most survey periods (winter surveys were not conducted) with highest abundances observed in March 2011 and July-August 2012, thought to coincide with movements of fish, particularly spring spawning herring, and other forage species (e.g. squid). Individuals typically occurred singly or in groups of 2-3, but groups of 5-8 also occurred, moving with the outgoing tide and occasionally feeding (circling behaviour); however more-detailed behavioural observations were not made. Movements and behaviour on the rising tide, as well as habitat utilization throughout the tidal cycle in the area are not known.

Fundy Tidal Energy Demonstration Site, Seabird Surveys—Minas Passage, 2008-2012.

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Seabirds are important in the marine ecosystem of the Bay of Fundy, and in the context of tidal power development, they have the potential to interact with tidal turbines and be affected by associated activities. The location of the tidal energy demonstration site on the shore of the Minas Passage—the location of the highest tidal currents—is known to support various seabird and waterfowl species common to coastal environments in Atlantic Canada. As part of the EEM Program for the site, the Fundy Ocean Research Centre for Energy (FORCE) has carried out baseline and first-, second-, third-, and fourth-year monitoring studies in 2008 and 2009-2012, respectively on bird distribution and abundance to allow assessment of impacts in the vicinity of the tidal demonstration site. Shore-based coverage of seabird distributions at the site was obtained through most of the year, vessel survey coverage in summer for four years, and a comparison between shore- and vessel-surveys in summer 2012 were also made. Overall, 47 species of water-associated birds have been identified from Minas Basin, Minas Passage and Minas Channel area. Apart from species commonly occurring in NS waters, the surveys identified some accidental species such as Northern Fulmar (a subarctic species) as well as noted distribution shifts of Pacific Loon—a species, which was thought to be rare in Atlantic Canada, but which has been regularly seen at the site during the Spring and Fall migration and in summer. An overview of all seabird vessel and shore-based survey data will be presented.

Seasonal Variability of Total Suspended Matter in Minas Basin, Bay of Fundy

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Minas Basin, at the eastern end of the Bay of Fundy in Nova Scotia, is a large macro-tidal estuary. Strong currents associated with the extremely large tidal water level range could potentially provide a source of renewable tidal energy but are a fundamental part of the Bay of Fundy ecosystem. Significant extraction of tidal energy could lead to local and far field changes in the tidal regime and sediment dynamics. Observations of total suspended matter (TSM) concentrations were derived from ocean colour imagery (MERIS data) in Minas Basin from May 2008 to July 2011. Analysis of time series of TSM in 1-km-square pixel boxes throughout the Basin revealed an annual cycle in TSM in most parts of the Basin. Larger TSM was observed in mid-winter (Feb. - Mar.), and smaller TSM characterized mid-summer (Jul. - Aug.). The largest annual variation occurred in the center of Minas Basin, and the smallest variation occurred in shallow areas. Satellite-derived TSM were compared to predictions using the Delft3D model. Increasing model erosion rate in winter relative to summer was necessary to improve agreement between model and satellite-derived TSM. Relative to satellite- derived estimates, the model overestimated TSM in shallow areas in summer and underestimated it in winter. This discrepancy is likely due to inaccurate satellite-derived TSM in shallow, high concentration areas of the Basin.

On the Melt Rate of Submerged Sediment-Laden Ice

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Submerged sediment-laden ice blocks that form on the intertidal mud flats of the Minas Basin pose a potential threat to tidal turbines planned for deployment in the Minas Passage. We report on results from laboratory investigations of the melt rate of sediment-laden and sediment-free ice, aimed at determining probable upper limits to the lifetimes of submerged ice blocks in the field.

Laboratory prepared ice blocks of varying sediment content, salinity, and length scale were melted in seawater of different far-field temperatures. The effect of sediment inclusions on melt rate is related to changes in heat supply and heat requirement to melt a unit mass of sediment-laden ice, where the former is affected by the strength of the convective current and the latter by the ice block properties. At small length scales sediment inclusions decreased melt rate due to cohesion, creating a sediment coating between the convective heat flow and the ice surface with insulating properties, and reducing the sediment concentration of the meltwater turbidity current. Both effects decrease the rate of heat supply to the ice surface. Heat flow increases with length scale to approach that of sediment-free ice such that large sediment-laden ice blocks melt faster than sediment-free ice due to decreased heat requirement.

The model has been used to predict lifetimes of large submerged ice blocks using far-field temperatures representative of seawater in the Minas Basin in February and March. The predicted lifetime of a 5,000 kg freshwater sediment-laden ice block is approximately 115 hours in 1°C seawater.

The Levelized Cost of Energy and the Importance of Cash Flow Risk Analysis

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The levelized cost of energy calculation (LCOE) is a consensus measure, and industry standard, for comparison of different energy sources, both conventional and renewable. The LCOE calculation allows for comparison of cost, and performance, of various energy sources when differences in scales of operations, financial investment, and/or economic lives exist. The calculation uses the Gordon Growth Model to discount cash flows at the appropriate risk-adjusted cost of capital, in order to determine the breakeven cost of the energy source. The output from the calculation can be seen as the average price energy consumers would need to pay in order for investors and project developers to exactly cover all of the costs needed to produce the energy.

In order to obtain financing to further the development of tidal energy in Nova Scotia, the levelized cost of energy must not only be accurately communicated, but also accurately calculated. The LCOE calculation produces a single-point estimate of the cost of the energy source, based on estimated future expected cash flows. Because cash flows cannot be estimated with precision, there is risk involved. In order to adjust for this risk, it is appropriate to conduct a cash flow risk analysis. A cash flow risk analysis can be conducted in terms of scenario analysis, sensitivity analysis, a Monte Carlo simulation, or a combination of the 3 methods. An overview of the levelized cost of energy calculation will be presented; outlining what is to be included in the calculation, the appropriate discount rate, and the benefits and limitations of the calculation's output. In addition, an explanation of the 3 cash flow risk analysis methods will be given, including the benefits of their use.